Aggregation and stranding of elongate sunfish (*Ranzania laevis*) (Pisces: Molidae) (Pennant, 1776) on the southern coast of Western Australia

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Abstract

Despite a global distribution and moderate abundance in temperate and tropical seas, the biology of *Ranzania laevis* (Family: Molidae) (Pennant, 1776) is very poorly understood. In autumn/winter 2008, numerous schools of *R. laevis* appeared on the south coast of Western Australia and several hundred individuals were washed ashore. Many of these fish were alive or recently deceased when found, creating a rare opportunity to study this species. Data on length, weight, diet and reproductive status obtained from stranded fish during this unusual event is described in the context of previously published information about this species. All fish examined appeared to be adults ranging from 300 to 700 mm total length. The ratio of males to females was 2:1. Gonad development indicated spawning was not imminent. The cause of the strandings was unclear, although advection of fish to the south coast by the tropical Leeuwin Current was strongly implicated.

Key words: slender sunfish, *Ranzania laevis*, fish kill, southern Western Australia

Introduction

Ranzania laevis (Family: Molidae), or elongate sunfish, has a worldwide distribution in temperate and tropical seas as far north as Scandinavia and as far south as New Zealand (Fraser-Brunner 1951; Hutchins 2001). It is an oceanic species found at depths of 0 m to >300 m (Leis 1977; Watson 1996). The biology and ecology of *R. laevis* is poorly understood, presumably because individuals have an inaccessible distribution and are rarely observed near land, and also because they are not fishery targets and have low commercial value. Existing knowledge of *R. laevis* has been derived mainly from individuals found stranded on beaches or caught accidently in deep ocean fishing operations (*e.g.* Fitch 1969; Ebenezer & Joel 1984; Iddison 2002). As a consequence, many of the published descriptions of this species have been based on specimens that were decomposed, damaged and/or of obscure origin.

Ranzania laevis is often reported as being solitary but, unlike other molid species, adults and juveniles also frequently aggregate (Fraser-Brunner 1951; Robinson 1975; Hutchins 2001). Schools comprising >500 individuals have occasionally been observed (Castro & Ramos 2002). The factors influencing aggregating behaviour are unclear. Aggregations are sometimes associated with warm water masses, although this behaviour could also be a response to be prey availability (Castro & Ramos 2002). *Ranzania laevis* consume small fish and planktonic invertebrates and so are probably attracted to areas of high productivity, such as upwelling and convergence zones, where these prey are abundant (Fitch 1969; Robinson 1975; Dulcic *et al.* 2007).

Individuals and small aggregations of *R. laevis* have previously been reported in coastal waters of south-western Australia (Walker 1983; Gomon *et al.* 2008). This region is strongly influenced by the tropical Leeuwin Current, which flows southward along the west coast throughout the year. In autumn/winter (April–August), the current strengthens and extends southwards along the full length of the west coast and then eastwards along the south coast (Smith *et al.* 1991). This process transports warmer water and various pelagic species to the more temperate region of the south coast (Maxwell & Cresswell 1981; Caputi *et al.* 1996; Gopurenko *et al.* 2006). Transport potential varies according to substantial interannual variations in current strength. The Leeuwin Current is typically stronger during a La Niña year and weaker during an El Niño year (Feng *et al.* 2003).

In April–June 2008, numerous schools of *R. laevis* appeared on the south coast of Western Australia and several hundred individuals washed ashore. Many of these fish were alive or recently deceased when found, creating a rare opportunity to obtain biological information about this species. This paper summarises information on length, weight, diet and reproductive status obtained from stranded fish in 2008 and briefly describes the environmental conditions occurring at the time of, and possibly contributing to, this unusual event.

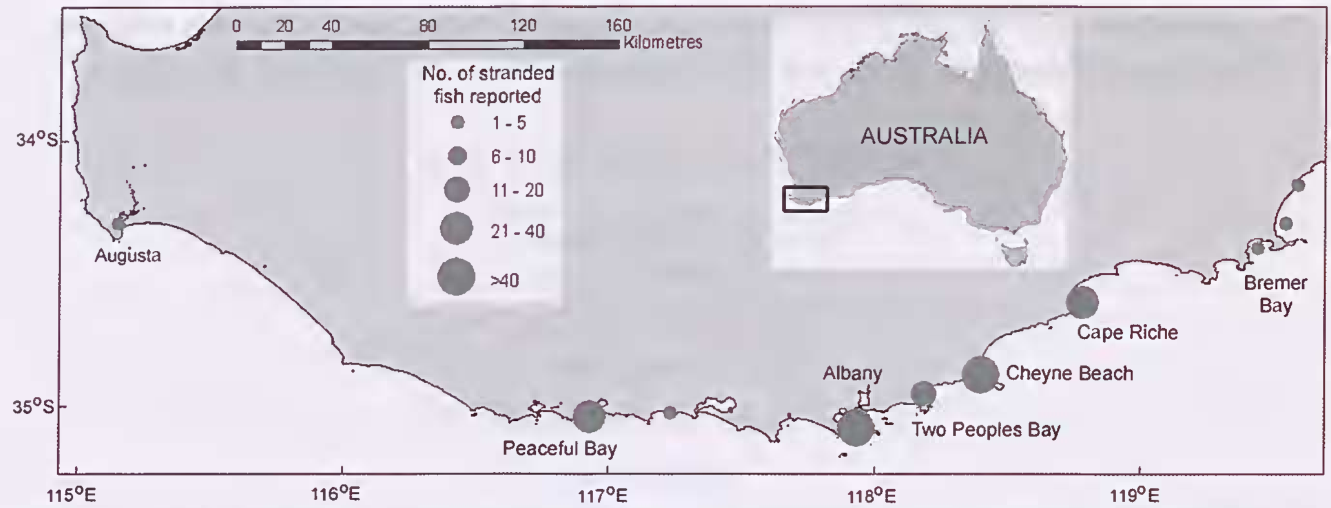

Figure 1. Locations and total numbers of *Ranzania laevis* sighted by researchers and the public between February and June 2008 along the south coast of Western Australia.

Methods

Trends in regional ocean temperature since 1982 were available from satellite-derived monthly mean sea surface temperature (SST) for the 1-degree latitude x 1-degree longitude block containing Albany (*i.e.* 35–36° S, 117–118° E) (Reynolds & Smith 1994). Sea surface temperature images were downloaded from http://www.marine.csiro.au/remotesensing. Intermittent records of beach and inshore water temperature for the Albany region were available from unpublished Department of Fisheries data.

Mean annual sea level at Fremantle, Western Australia, was used as an index of annual Leeuwin Current strength. There is a strong linear relationship between Leeuwin Current volume transport and sea level deviation at Fremantle (Feng *et al.* 2003).

Following initial sightings of stranded *R. laevis* in early May 2008, two relatively fresh fish were collected from Cheyne Beach near Albany (Figure 1) and examined by a pathologist to determine a cause of death. Fish were examined for evidence of pathogens, parasites, poisoning or other injury. Thin sections of heart, gonad, gill, spleen and liver were examined histologically. Lengths and weights of these fish were not recorded.

A media campaign was implemented in late May 2008 to encourage members of the public to report sightings of sunfish. The public was asked to report the number, date, location and total length of each fish observed.

During May and June 2008, specimens were collected for biological analysis by researchers and by the public. Some biological data was not obtainable from decomposed or damaged fish. Morphological variation was clearly evident during initial observations of fish and so measurements of total length, maximum height (*i.e.* distance between tip of dorsal fin and tip of anal fin), height at insertion point of pectoral fin, height at clavus (*i.e.* distance between base of dorsal fin and base of anal fin) and whole body weight were taken from each fish in an attempt to quantify this variation.

Gonads were extracted and weighed. Gender was determined from macroscopic examination and a macroscopic gonad developmental stage was assigned based on the scheme of Laevastu (1965) where stage 1 = immature virgin; 2 = maturing virgin or recovering spent; 3 = developing; 4 = developed; 5 = mature; 6 = spawning; 7 = spent. All gonads were found to be at a similar macroscopic stage. Ovaries from three relatively fresh specimens (total length range 510–550 mm) were placed in 10% formalin solution for several weeks and then examined microscopically (histologically) to corroborate the macroscopic staging. A transverse section was removed from the middle of one lobe of each preserved ovary and processed using standard histological techniques to produce a 7 μm section, which was stained with Harris's haemotoxylin and eosin prior to microscopic examination. Ovarian development stages were assessed microscopically from the identification of the most developed oocytes (Yamamoto *et al.*, 1965; Wallace & Selman, 1981).

Stomachs were retained from 19 relatively fresh fish, collected between 13 and 16 May 2008 from Frenchman Bay and Cheyne Beach near Albany (Figure 1). Stomachs were preserved in 10% formalin. Stomach contents were later extracted, identified and weighed.

Samples of dorsal fin from 20 fish were retained and stored in 90% ethanol for future genetic analyses (not examined in this study).

In an attempt to estimate age, the inner ears from three fish were extracted and examined under a dissecting microscope for otoliths. However, no otoliths were present. Some microscopic calcareous granules were found, which were similar in appearance to the otoconia found in *Mola mola* (Thompson 1888).

Results

Ocean conditions

Regional mean monthly ocean temperature was 19–20 °C from April to June 2008, which was well above the long-term average for each month (Figure 2). Relatively high regional water temperatures coincided with the presence along the south coast of the Leeuwin

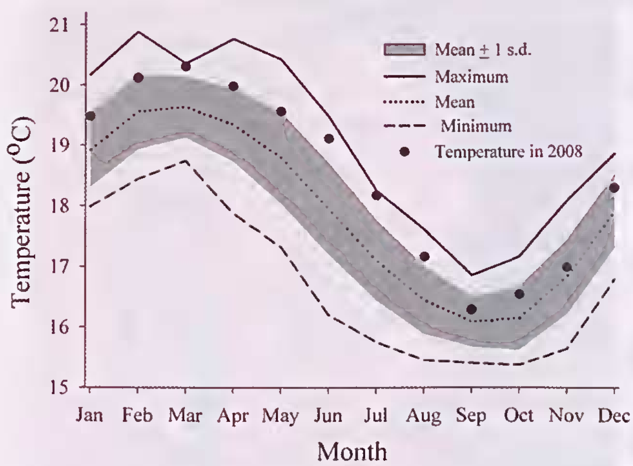

Figure 2. Satellite-derived maximum, minimum and mean (± 1 standard deviation) monthly sea surface temperatures in the Albany region from 1982 to 2007 and mean monthly sea surface temperatures for 2008.

Current. Mean annual current strength in 2008 was the highest since 2000 and one of the strongest years on record (Figures 3 and 4).

At Albany, beach and inshore (*i.e.* up to 10 km from shore) water temperatures were 19–20°C in both April and June 2008 (K. Smith, unpubl. data; N. Chambers, pers. comm.). No records of beach water temperature were available for May. Local residents and commercial fishers reported that beach water temperatures were 'unseasonally warm' at the time of strandings.

Pathology

There was no evidence of any infectious disease or injury causing the death of stranded fish. There appeared to be no major physical damage to any stranded fish, including the gills, although there were some scratches on the skin consistent with abrasion on sand or reef. No external parasites were reported on any stranded fish.

There were no significant histological abnormalities found in sections of heart, gonad, gill and spleen (J. Creeper, pers. comm.). One fish had an enlarged spleen relative to the other fish examined. Also, infections of the wall of the gastro-intestinal tract by encysted metacestodes and an inflammation of the small intestine associated with myxosporidian protozoans were found.

The stomachs of fish examined by pathologists were relatively empty. The appearance of the liver in these fish was suggestive of hepatic lipidosis, where lipids are mobilised in the liver in response to a prolonged period without adequate food (J. Creeper, pers. comm.) (Figure 5A).

Distribution of fish

Between February and June, a total of 322 *R. laevis* were sighted by members of the public and researchers along 520 km of coastline on the south coast of Western Australia, between Augusta and Point Anne (east of Bremer Bay) (Figure 1). The fish occurred as individuals or in small schools (<50 fish) and were observed whilst either stranded on a beach or swimming in shallow waters immediately adjacent to the shore (*i.e.* within 500 m of the shore). The majority of sightings occurred at Albany (40%), Cheyne Beach (37%), Cape Riche (11%), Peaceful Bay (7%) and Two Peoples Bay (4%).

With the exception of a single fish observed on 15 February at Augusta, all fish reported in 2008 were observed between 7 April and 24 June 2008, with the majority (89%) of reported sightings occurring in May. No reports were received of fish swimming in waters further offshore during this period.

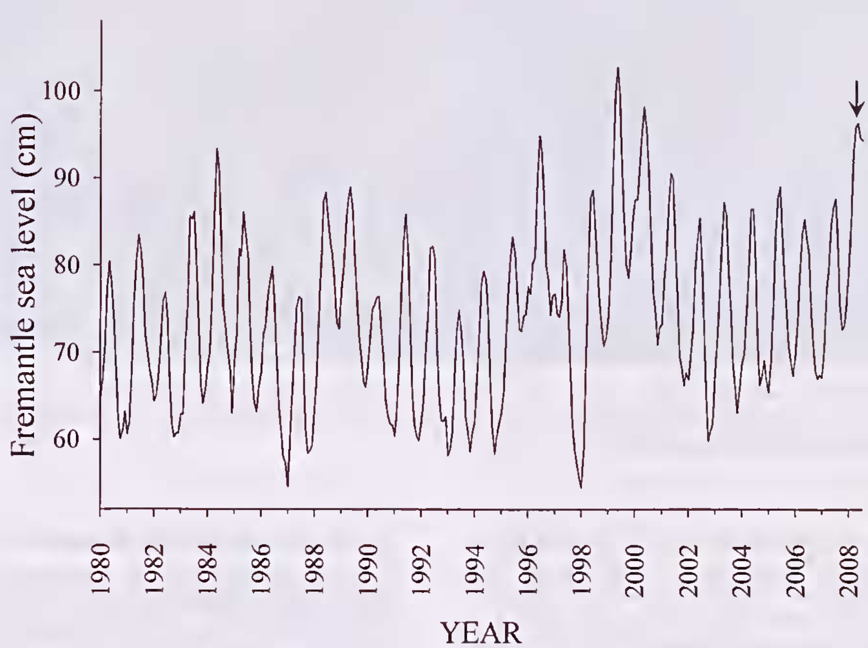

Figure 3. Mean monthly sea level at Fremantle, Western Australia, from 1980 to 2008 (3-month moving average). Fremantle sea level is an index of Leeuwin Current strength. Timing of strandings in 2008 indicated by arrow.

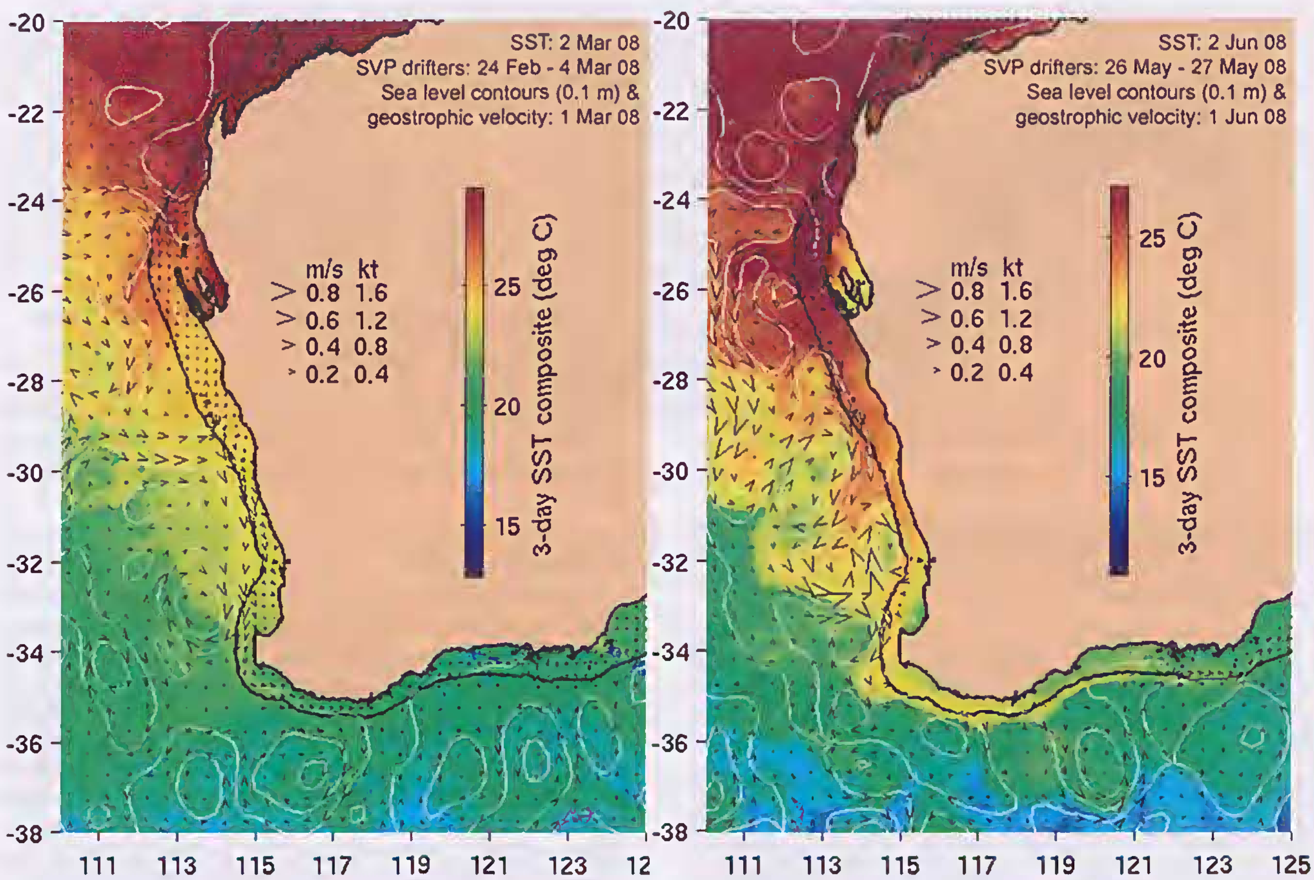

Figure 4. Sea surface temperature images indicating position of Leeuwin Current on A) 2 March and B) 2 June 2008. Images downloaded from http://www.marine.csiro.au/remotesensing.

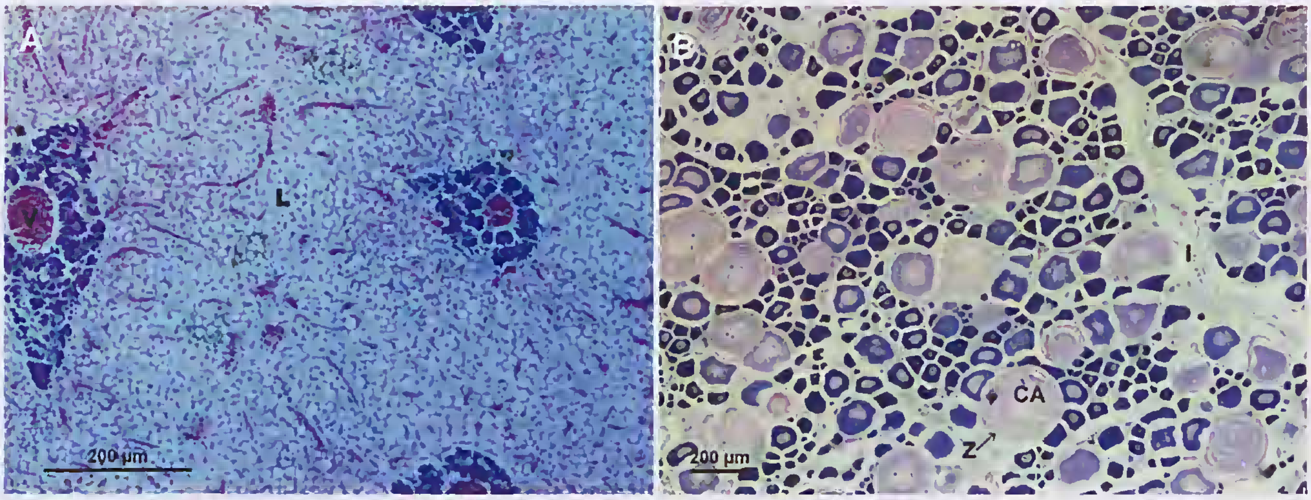

Figure 5. Histological sections from stranded *Ranzania laevis* sampled in May 2008. A) liver displaying abundant lipid vacuoles (L) (clear, spherical); blood vessels (V) also evident. B) ovary showing cortical oleoli (CA) stage oocytes, including well developed zona radiata (Z), and intralamellar stromal strands (I).

In addition to the above sightings, a commercial fisher observed a large school, estimated to comprise 300–350 fish, which swam in shallow waters off Cheyne Beach for 3–4 weeks in early June 2008. None of these fish became stranded while being observed. Overall, this school and the above mentioned stranded fish comprised nearly 700 observed individuals.

Length, weight and sex composition

The total lengths of 95 stranded fish were measured. Of these fish, it was possible to determine the gender of 39 individuals. Gender could not be determined in badly decomposed fish and was not known from specimens reported by the public. The ratio of identified males to females was 2:1. The lengths of stranded fish were

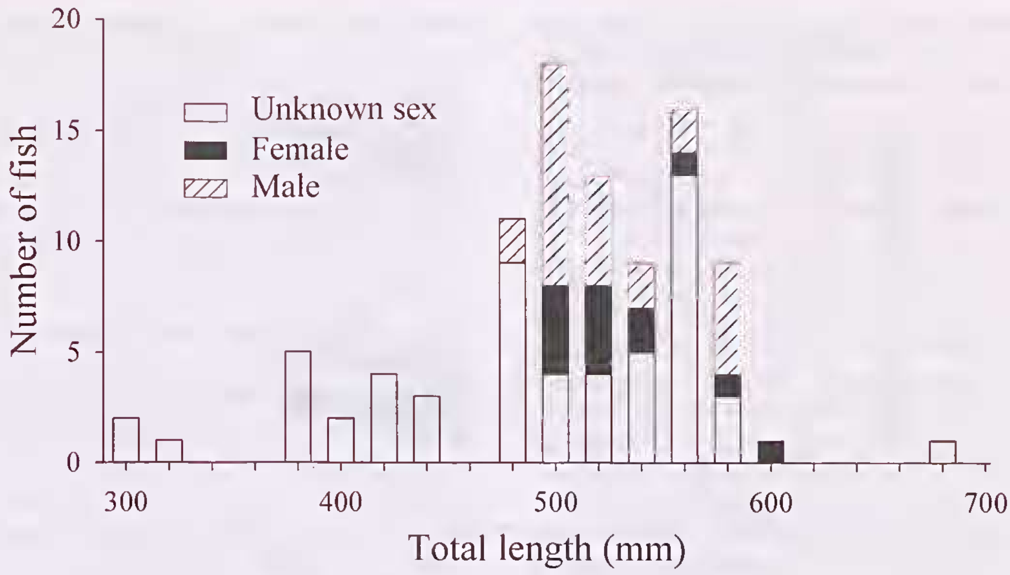

Figure 6. Length frequencies of *Ranzania laevis* sampled between February and June 2008 along the south coast of Western Australia.

reported to range from 300 to 700 mm (Figure 6). Identified males ranged from 490 to 590 mm and females from 506–619 mm.

Relatively few (n=22) undamaged, fresh fish were available to be weighed. The lengths of these fish ranged from 498 to 619 mm. Over this limited range, there was a linear relationship between length and whole body weight:

W = 0.3412 L + 374.93 (where W is weight in g, L is total length in mm).

With the addition of previously published values for similar and smaller sized individuals of *R. laevis*, the combined data suggested the following relationship:

W = 74.369 x L $^{0.321}$ (where W is weight in g, L is total length in mm) (Figure 7).

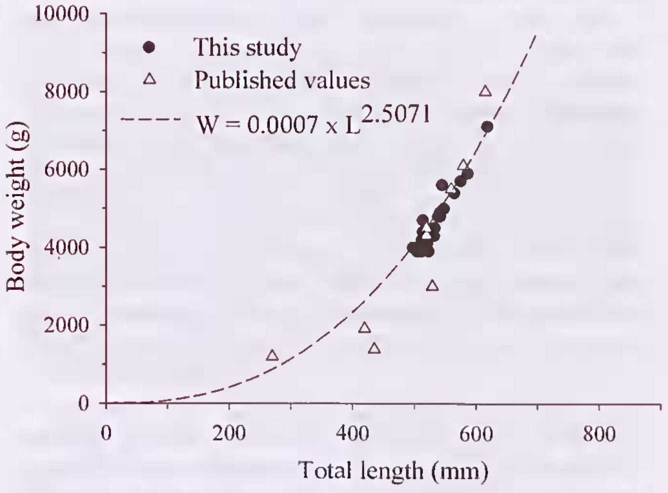

Figure 7. Total length versus total weight of *Ranzania laevis* sampled in 2008 along the south coast of Western Australia and other published values for this species. Data from males and females are pooled. Sources of published values: Specchi & Bussani 1979; Jardas & Knezevic 1983; Walker 1983; Ebenzer & Joel 1984; Iddison 2002.

Over the length range of fish examined in this study, there was clear evidence of an ontogentic change in body dimensions. Small fish were considerably more elongate than larger fish (Figure 8). Body height at the insertion point of the pectoral fin increased from approximately 40% of the total body length at 300 mm to 50% at 650 mm. Maximum height (distance between tips of dorsal and anal fins) increased from approximately 70% of the total body length at 300 mm to 90% at 650 mm.

Reproductive status

Where gender could be determined, all individuals were found to be sexually mature. With the exception a single male fish at stage 2, all other gonads were found to be at macroscopic developmental stage 3 (100% of females and 96% of males). At stage 3, male and female gonads weighed between 0.53 and 1.37% of whole body weight. The weight of the stage 2 testes was 0.02% of whole body weight.

Examination of the microscopic characteristics of ovaries identified the most advanced oocytes in all three specimens as having formed cortical alveoli (CA) and lipid droplets within the cytoplasm (Figure 5B). This oocyte stage indicated that these were Stage 3 'developing' ovaries and that they were dissected from mature females that were in the early stages of commencing vitellogenesis. The identification of well-formed zona radiata for several CA oocytes further confirmed this development stage, although relatively poor preservation obscured any more advanced vitellogenic features within the cytoplasm of these oocytes (Figure 5B). Multiple oocyte development stages indicated asynchronous oocyte development, which suggested that females of this species are serial batch spawners. The maximum oocyte diameter in each ovary ranged from 210 to 274 μm. The presence of broad intralamellar stromal strands in two ovaries indicated that those fish had spawned previously (Figure 5B).

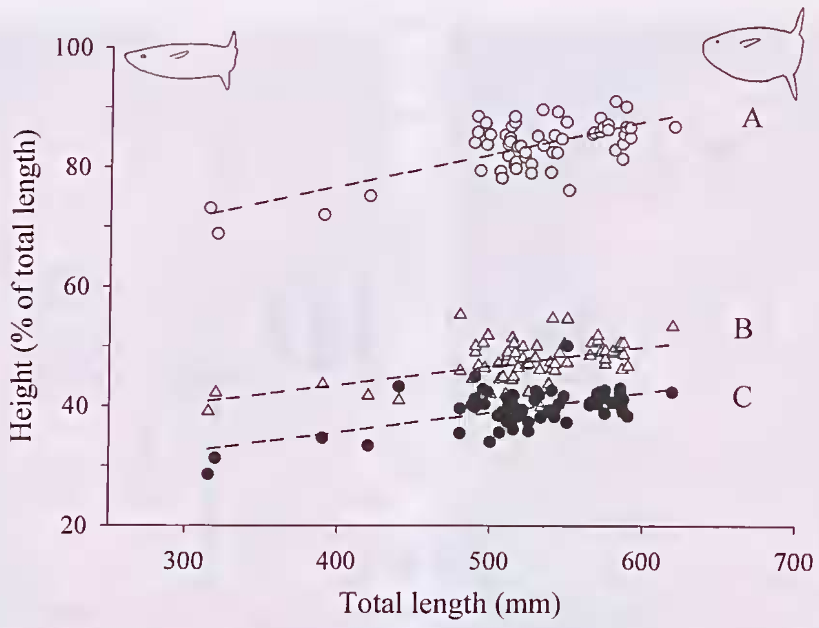

Figure 8. Total length versus A) maximum height, B) height at insertion point of pectoral fin, and C) height at clavus, expressed as a percentage of total length. Measurements by Raven (1939) from a single fish (315 mm) previously collected at Albany are also included. Regressions fitted A) Height = (0.0539 x Length) + 55.105 (r^2 = 0.4708); B) Height = (0.0314 x Length) + 30.925 (r^2 = 0.2445); C) Height = (0.033 x Length) + 22.374 (r^2 = 0.3314).

Stomach contents

Most stomachs were relatively empty. Four stomachs were relatively full and these contained predominantly seagrass. The weights of stomach contents ranged from 13 to 95 g per fish. Unidentified digested material comprised 77% by volume of total material examined (ranging from 20–100% per stomach) and seagrass (*Posidonia sinuosa* and *P. australis*) comprised 19% by volume of total material examined (ranging from 0–80% per stomach). Invertebrates comprised about 1% of total material examined (ranging from 0–5% per stomach). Sand/rock and a feather were also present.

Discussion

To our knowledge, the only other published report of a mass stranding of *R. laevis* is also from the Albany region, where approximately 50 individuals washed ashore in 1928 (Gomon *et al.* 2008). Anecdotal reports from commercial fishers and others suggest that *R. laevis* strandings are relatively common along the south coast, with small numbers of fish being sighted here in most years (G. Kennedy & G. Jackman, pers. comm.). All past sightings of stranded fish along the south coast have occurred from April to June, coinciding with the maximum flow of the Leeuwin Current in this region. Unfortunately, none of the people we interviewed were able to recall the precise number of fish observed in any previous year or the particular year(s) in which sightings had occurred. However, all agreed that the number of *R. laevis* stranded along the south coast was substantially higher in 2008 than in any previous year.

In 2008, the strength of the Leeuwin Current was well above average. In addition, limited data suggest that the Leeuwin Current may have flowed unusually close to the shore in 2008. This current typically flows along the edge of the continental shelf and so beach temperatures usually reflect cooler shelf waters rather than the warmer waters of the Leeuwin Current. However, commercial fishers reported atypical ocean conditions at the time of the strandings, including above average beach water temperatures and the presence of various tropical species not commonly found near the shore in this region. The transport of a relatively high volume of warm water to the south coast by the Leeuwin Current, accompanied by a greater than average shoreward distribution of the current flow could explain the exceptional number of *R. laevis* occurring near the shore in 2008.

The above information suggests that *R. laevis* are transported to the south coast annually by the warm waters of the Leeuwin Current. *Ranzania laevis* is generally reported from waters >20 °C (Robinson, 1975; Sokolovskaya & Sokolovskiy 1975; Castro & Ramos 2002; Wan & Zhang 2005). The surface temperature of the Leeuwin Current as it flows along the south-western Australian continental shelf in autumn is usually >20 °C, which is typically 2–4 °C warmer than ambient surface temperatures (Rochford 1984; Smith *et al.* 1991; Cresswell & Peterson 1993). Hence, the surface waters of the Leeuwin Current are generally at a suitable temperature for *R. laevis* and could host individuals of this species whilst advecting them to the south coast.

A total of nearly 700 fish were observed on/near beaches in April–June 2008. It is likely that additional fish occurred at remote locations and were not observed. Therefore, the actual number of fish in the region at this time was almost certainly higher than that observed. Individuals and small schools were simultaneously observed in different locations that extended along 100's km of coastline, suggesting that these fish were actually part of a very large, dispersed aggregation of fish present along the south coast.

The advection of large numbers of *R. laevis* within a warm water mass has also been reported in the central east Atlantic. In May–July 2002, a very large aggregation of *R. laevis* comprised of solitary fish and schools of >500 fish was observed off the Canary Islands (latitude 28° N). Their appearance coincided with the arrival of a warm water mass (21–23° C), which was 3–5° C warmer than the surrounding surface waters (Castro & Ramos 2002).

The large aggregations of *R. laevis* along the south coast of Western Australia and off the Canary Islands were not associated with spawning. The Canary Islands aggregation was comprised of fish 20–25 cm in total length, which were probably juveniles (see below). The Western Australian aggregation probably consisted entirely of adults, but they were not in spawning condition. Spawning and gonad development in *R. laevis* has not been described although Jardas & Knezevic (1983) observed a single male with a "fully ripe testes" (probably equivalent to macroscopic stage 5) of *R. laevis* that comprised 9.13% of total body weight and occupied a major part of the abdomen. In contrast, most fish sampled in May 2008 possessed gonads that weighed between 0.53 and 1.37% of whole body weight. In addition, the presence of cortical alveoli oocytes with lipid droplets as the most advanced oocyte stage within all specimens microscopically analysed indicated that these fish were not spawning at the time of sampling.

Limited evidence suggests that *R. laevis* attain maturity at a total length of approximately 300 mm. Published reports of "adults" describe fish that are >300mm, whereas individuals reported to be juveniles or of indeterminate sex are <300mm (Sherman 1961; Fitch 1969; Robinson 1975; Jardas & Knezevic 1983; Ebenezer & Joel 1984; Iddison 2002; this study). *Ranzania laevis* is reported to attain a maximum total length of 900 mm (Hutchins 2001). However, we were unable to find a published account of any particular fish above 700 mm. Hence, the fish observed off south-western Australia in 2008 apparently comprised the full size range typical for adults of this species (*i.e.* 300 to 700 mm).

In 2008, stranded fish had apparently not fed for at least a few days prior to stranding. The stomachs examined were relatively empty except for seagrass. Vegetation has been found previously in stomachs of *Ranzania laevis* although it is unclear whether ingestion of vegetation by this species is incidental (Fitch 1969). Seagrass is abundant in the Albany region and large accumulations of dead leaves were present in shallow waters and on the beaches where fish were stranded. It is possible that seagrass was ingested incidentally, either while attempting to prey on invertebrates or during the process of stranding.

Incidental ingestion of seagrass during stranding is possible, given the permanently open mouth. Conflicting reports exist about the mouth morphology of *R. laevis*. The mouth opening forms a wide oval (with long axis in the vertical plane) and some authors have reported that it closes to form a vertical slit (Fraser-Bruner 1951; Ebenezer & Joel 1984). However, others have reported that it is a relatively inflexible structure and remains permanently open (Fitch 1969; Robinson 1975; Iddison 2002). The living and dead specimens observed in south-western Australia in 2008 had open mouths that were apparently inflexible and permanently open.

Evidence from the small number of fish examined by pathologists was inconclusive in regards to nutritional status. These fish displayed symptoms consistent with hepatitic lipidosis seen in some fish species, where lipids are mobilised in the liver in response to starvation or nutritional imbalance (Wolf & Wolfe 2005). However, members of the related family Tetraodontidae typically have a high lipid content in their livers and so this condition may also be typical in Molidae (Ando *et al.* 1993; Hazra *et al.* 1998). Further sampling to determine 'normal' liver condition in *Ranzania* would be required.

The cause of strandings is not clear. Adult *R. laevis* are normally strong, agile swimmers that would be capable of avoiding stranding (Gomon *et al.* 2008). Adults have been observed swimming rapidly near the surface and even jumping completely out of the water (G. Kennedy & G. Jackman, pers. comm.). Burst speeds of 90–100 cm/second have been reported for juveniles (Robinson 1975). Also, the structure of the fins and musculature are suggestive of fast swimming (Raven 1939). However, the fish that stranded were evidently weak and disoriented. In 2008 and in earlier years, stranded fish were 'rescued' by members of the public and commercial fishers who returned them to deeper waters, but the fish quickly swam back to the beach and became stranded again. Some fish were observed to strand during very calm weather, and so storm surge was not a primary cause of strandings.

In summary, the reason for the mass strandings of *R. laevis* off south-western Australia in 2008 and in previous years remains unclear. However, it is likely that individuals of this species are transported to this region annually by the Leeuwin Current. This current mainly flows over the shelf break but eddies and meanders could occasionally transport fish towards the shore. Starvation due to low prey availability within the Current may weaken individuals en route to the south coast and contribute to strandings.

Given the apparent relationship between strandings and the Leeuwin Current, it is likely that strandings in this region will continue to occur periodically and could be forecast from oceanographic data. In 2008, a substantial amount of data, including specimens and numerous photographs, were provided by the public. In future, the length-height ratio could be a useful method of estimating fish length from photographs provided by the public.

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